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RADIO TRACKING OF MARINER II AND ITS SCIENTIFIC IMPLICATIONS

Precise two-way Doppler tracking of Mariner II during its 129-day flight to Venus and beyond has provided scientists with basic information that will help further refine physical constants that are important in understanding the solar system and the earth.

Using the data obtained, the scientists will be able to apply themselves to getting, with more certainty than now available, such figures as:

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The mass of Venus

The precise location of tracking stations on the earth.

The value of the Astronomical Unit. (The AU is the mean distance between the sun and the earth)

The mass of the earth's moon.

"The high accuracy and great volume of Mariner tracking data will serve as a stimulus to workers in celestial mechanics to combine radio tracking data, radar astronomy data and optical data, they said.

The long term results of such a combination will resolve existing incompatabilities in experimental results and dramatically advance our ability to describe the mechanics of the solar system. This clearly is needed for accurate navigation and guidance for more advanced missions."

Before the Mariner mission, they said, it was suspected that uncertainties in some of the solar system physical constants -- such as the AU -- would make it difficult, if not impossible, to use ground based radio guidance techniques to command a spacecraft to hit a planet. It was suspected that it would be necessary to use some sort of "homing" device on the spacecraft so that it could "sense" the planet and home in on it.

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"Now it appears," they said, that simpler earth based radio guidance techniques will remain competitive to on board guidance measurements and computation techniques until extremely precise target error control is desired.

For example, it was pointed out, on December 7 -- one week before the Mariner encounter with Venus -- the position of the spacecraft with respect to Venus was uncertain to only 800 miles -- mostly due to the positional uncertainty of Venus with respect to the earth. The closest approach of Mariner with respect to Venus was 21,648 miles.

Now, as the precise tracking data have been analyzed, it is possible to reconstruct the position of the spacecraft with respect to Venus to within 10 miles at encounter.

More than 22,000 two-way Doppler data points were taken during the 129-day Mariner mission, and it is the volume and precision of these data points that are proving so useful in refining the trajectory.

Two-way Doppler is a precise method of measuring radial velocity of a spacecraft by using the well known Doppler shift in frequency in a radio signal between two moving objects. This effect is what causes the sound of a train whistle to rise in pitch as the train approaches and drop in pitch as it passes. Two-way doppler is an extremely precise method of determining the shift in the radio signal frequency.

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In the Mariner mission, the Goldstone tracking station of the Deep Space Instrumentation Facility transmitted a signal to Mariner. The signal, received at the spacecraft, was shifted in frequency by the Doppler effect, and then was retransmitted by the spacecraft to Goldstone. The signal received at Goldstone was further shifted by the velocity of the spacecraft in relation to the station.

Velocity changes so precise as to be on the order of one tenth of one inch per second were measured by this two-way Doppler tracking.

Using these data, it was possible to calculate exactly how the Mariner trajectory was perturbed by the gravity of Venus as Mariner flew by Venus.

The size of this perturbation and the accuracy of its determination, then, is extremely useful in determining the mass of Venus.

Classical astronomers, using data on the perturbation of the orbits of other celestial bodies caused by Venus and collected over several decades, have calculated the mass of Venus to be 0.8148, of the mass of the earth. The probable error is 0.05 per cent.

The Mariner data -- collected over two weeks, one week before and one week after encounter -- has a potential to determine Venus mass with a probable error of 0.005 per cent.

Another significant result obtained was the absolute location of the Goldstone station. Before the Mariner mission, the exact location of the Goldstone station had been known to within 100 yards. After Mariner's data have been analyzed, it will be known to within 20 yards.

The way the station location is determined from the Doppler data may be understood by supposing the spacecraft to be fixed in space with respect to the center of the earth. The only Doppler tone observed would be caused by the station's rotational velocity component along the direction to the spacecraft.

The observed Doppler tone at the station depends, then, on the latitude, longitude and radius from the center of the earth. Since many measurements were obtained during many passes at the DSIF stations, it will be possible to deduce the proper combination of station location errors to match the data.

The mass of the moon may be determined by similar reasoning from the data, the scientists said. In this case, the variation in Doppler tone is due to the movement of the earth around the earth-moon system's center of mass, or barycenter. The earth makes one revolution around this barycenter every 28 days at a speed of 27 miles an hour.

Of the three items that influence this motion -- the earth's mass, the moon's mass and the earth-moon distance, the moon's mass is the least well known. The moon's mass is now known to a certainty of 0.1 per cent. The scientists hope that by analyzing the data it may be possible to reduce this present uncertainty to a smaller figure.

The Astronomical Unit -- the mean distance between the earth and the sun -- is used as the yardstick of the solar system. Data from classical astronomical observations have derived a value of the AU which is 50,000 miles different from the value derived by Venus radar bounces in 1961. The radar established AU is 92,956,220 miles, plus or minus 300 miles. The optical AU is 50,000 miles smaller.

A similar Venus radar bounce, conducted by the Venus station at Goldstone during the Mariner mission, produced the same result as the 1961 bounce also conducted at Goldstone.

The Mariner tracking data now provides an additional radio determination which will help resolve the conflict between the radar established AU and the AU calculated by optical measurements.

The results were reported by Thomas W. Hamilton, Chief of the systems analysis section of the California Institute of Technology Jet Propulsion Laboratory, and Donald W. Trask, supervisor of the orbit determination group of the same section at JPL.

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